Thesis/
Reports
Burgess,
R. L.
Con't.

SOIL MOISTURE, UNDERSTORY COMPETITION AND TREE GROWTH IN FOUR SHELTERBELTS IN SOUTHEASTERN NORTH DAKOTA: A CONTINUATION

Robert L. Burgess

SOIL MOISTURE, UNDERSTORY COMPETITION, AND TREE GROWTH IN FOUR SHELTERBELTS IN SOUTHEASTERN NORTH DAKOTA - A CONTINUATION

(Project No. 107-015-02-03)

(Order No. 19-RM-8-71)

Robert L. Burgess
Associate Professor of Botany[1]
North Dakota State University
Fargo, North Dakota

A Report Submitted To The

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION
U. S. Department of Agriculture, Forest Service
Fort Collins, Colorado

May 1971

LIBRARY COPY
ROCKY MT. FOREST & RANGE
EXPERIMENT STATION

1/ Present address: Deputy Director, Eastern Deciduous Forest Biome, Oak Ridge National Laboratory, Oak Ridge, Tenn.

SOIL MOISTURE, UNDERSTORY COMPETITION, AND TREE GROWTH IN FOUR SHELTERBELTS IN SOUTHEASTERN NORTH DAKOTA - A CONTINUATION

A series of four shelterbelts in southeastern North Dakota, part of a larger group of shelterbelts studied by Naylor (1969)[1], were selected for experimental study in the summer of 1968. All are older belts, at least 25 years of age, containing a minimum of five rows and a minimum of five species of trees. Two belts (Grandin and Kindred) are on heavy clay soils in the Red River valley of extreme eastern North Dakota, while the other two belts (Arthur and Buffalo) are on sandy soils slightly to the west on the ancient beach ridges of Glacial Lake Agassiz. Grandin and Buffalo possess a grassy understory, while at Kindred and Arthur, the developing understory vegetation is predominantly woody, consisting of a number of shrubs and a heavy admixture of seedlings and saplings generated by the overstory trees.

In each belt, paired 100-foot segments were selected, and one of each pair was clean-cultivated to remove the understory. Soil moisture samples have been obtained at intervals in six inch depth increments down to six feet in each segment (treatment and control) in each belt.

Five individuals of each of five species (BOX ELDER, COTTONWOOD, AMERICAN ELM, SIBERIAN ELM and GREEN ASH) were selected in each segment of each belt. At Buffalo, box elder forms the south row and Siberian elm the north row. Both rows were degenerate so at the Buffalo belt only the

---

1/ Naylor, J. N. 1969. Understory vegetation in shelterbelts in eastern North Dakota. PhD thesis, North Dakota State University, Fargo, N. D. 214 pp.

other three species were used. Each tree selected was marked with paint and height and diameter measured at the end of each growing season. Preliminary results were reported by Lakshmanan (1970)[2].

During the summer of 1970, each of the belts was visited a number of times. Maintenance of the cultivated segments required approximately two man-days in each belt. Originally, understory removal had entailed partial clearing with axes, machetes, and saws, followed by repeated tractor cultivation and power roto-tilling. Occasional hoeing and weed-pulling then maintained the treatment.

In 1970, most of the treatment segments were still fairly clean, so maintenance was accomplished by hoeing, raking, some pulling, and infrequent use of the machete on an occasional woody sprout. The main ground cover that had regenerated was an almost complete cover of dandelion (Taraxacum officinale L.) seedlings at Kindred, but these were easily removed by hoeing and then raking with a hand garden rake.

A series of soil moisture samples was obtained in each belt, once in late July, once in August, and again in early September. Soil moisture percentages for each segment in each belt on each of the three sampling dates are given in tables 1 through 4. In general, the pattern established in the previous two years of study prevails. Moisture levels tend to be higher in the control segments of the clay belts (more pronounced at Grandin than at Kindred), and higher in the cultivated treatment segments of the sandy belts. The indication that major rooting

---

2/ Lakshmanan, N. K. 1970. The effect of understory competition and soil moisture on the growth of shelterbelt trees in eastern North Dakota. PhD thesis, North Dakota State University, Fargo, N. D. 117 pp.

depth of the understory is at two to three feet is also evidenced by a general decline in moisture values at these depth increments in all belts.

Tree growth, both diameter and height, is listed for each individual in all belts in tables 5 through 8. Individuals in each species numbered one through five are in the treatment (clean-cultivated) segment of each belt; numbers six through ten are in the control segments. The growth increments are given for each individual for the 1970 growing season, along with the mean growth increment (diameter and height) for each species in each segment in each belt. This 1970 mean increment value is compared to the two-year means(1969 and 1970 growing seasons). While considerable variation is still evident, trends are beginning to stabilize. There is an apparent smaller variation in diameter increments than in height increments, but this is probably an artifact. Both parameters were measured in inches, probably accounting for the greater variability in the height increment measurements. For comparative purposes, Appendix tables 9, 10, 11, and 12, covering the 1968 and 1969 end-of-growing-season measurements, are included (Lakshmanan, 1970).

The two-year growth averages of the five tree species studied are summarized in bar graphs (Figures 1 through 5). Cottonwood (the largest trees in each belt) appear to be making the greatest absolute growth in all belts, although box elder is growing well at Grandin. Based on species growth rates available from other sources (including some measurements in native forests in North Dakota), all of the trees studied in all four belts appear to be growing very slowly.

Of the 36 comparisons in Figures 1-5, 26 (72 per cent) show an

advantage in the treatment segment. This is further reflected in Fig. 6, which shows combined averages for all species, compared as to treatment and soil type. Collectively, the clean-cultivated segments show better growth (on an absolute basis) than the control segments. Based on this analysis, however, diameter growth is greatest in the clay belts, while height growth is strongest in the sandy shelterbelts.

By combining average growth increments from all individuals in all belts (Fig. 7), the general advantage of the treatment segments is illustrated. To further explore this trend, the average diameter increments (per species, per segment, per belt) were tested against the average height increments (Fig. 8). The resulting strong positive correlation indicates that diameter and height growth increments can be combined, in the ratio of the given orthogonal axes, into a single index measurement.

By construction of an index ($I = 500X + 5Y$, where X = average annual diameter increment, and Y = average annual height increment), it is shown that while total differences are of small magnitude, trees in the treatment segments show a greater overall growth than trees in the control areas (Fig. 9). It is also evident that little difference in growth is manifested between the clay belts and the sand belts.

While not enough data are yet available to make adequate statistical tests, it seems as though all four belts can be used to assess the influence of understory vegetation on tree growth for all species under consideration. For individual species, reliance on the sand versus clay comparisons is still necessary, as evidenced by the variation in growth of box elder in the three belts where it occurs.

It can now be demonstrated, I believe, that cultivation in older shelterbelts in southeastern North Dakota has a beneficial effect on tree growth through the removal of understory competition. Whether or not the competitive effects are more significant with respect to moisture than to some other factor (or factor-complex, such as the nutrient regime, for instance) is still open to more investigation.

Table 1. Soil moisture percentages in the Grandin Belt (clay) in six inch increments to a depth of six feet on three dates in 1970. Data are given for treatment (clean-cultivated understory) and control segments (C) in the belt.

Depth	7/30/70		8/18/70		9/12 70	
	T	C	T	C	T	C
1	38.1	35.6	34.1	31.8	34.7	35.0
2	32.0	33.1	32.6	31.4	33.6	33.1
3	31.8	30.7	30.9	31.2	32.4	33.3
4	28.6	29.8	24.5	27.9	30.7	29.0
5	27.5	30.4	27.0	26.3	25.8	30.1
6	27.7	29.6	26.5	26.8	24.8	27.5
7	27.5	31.2	28.3	26.4	26.0	26.3
8	28.9	35.3	27.8	28.9	25.3	24.8
9	30.2	36.2	20.9	27.3	27.4	26.7
10	33.0	36.2	26.4	26.5	29.8	28.2
11	32.4	36.8	29.1	28.9	28.5	28.9
12	36.1	40.1	33.6	34.0	31.0	31.8

Table 2. Soil moisture percentages in the Kindred Belt (clay) in six inch increments to a depth of six feet on three dates in 1970. Data are given for treatment (T) (clean-cultivated understory) and control segments (C) in the belt.

Depth	7/29/70		8/20/70		9/10/70	
	T	C	T	C	T	C
1	40.6	37.2	31.7	30.8	31.6	28.5
2	39.8	35.1	27.3	28.4	27.6	27.3
3	35.6	32.0	26.9	27.0	26.5	24.2
4	32.0	33.2	27.2	27.1	27.0	24.1
5	30.1	30.5	28.5	27.5	25.2	22.9
6	28.0	26.6	25.0	26.3	26.3	25.8
7	26.5	27.1	24.7	25.2	25.8	25.2
8	26.5	26.2	25.2	25.9	27.6	28.0
9	27.8	28.9	24.3	26.7	28.0	29.6
10	29.6	27.4	26.9	25.1	26.9	29.0
11	26.4	28.8	28.6	27.4	28.3	31.5
12	29.8	29.7	28.4	29.2	29.5	28.4

Table 3. Soil moisture percentages in the Arthur Belt (sand) in six inch increments to a depth of six feet on three dates in 1970. Data are given for treatment (T) (clean-cultivated understory) and control segments (C) in the belt.

Depth	7/31/70		8/21/70		9/15/70	
	T	C	T	C	T	C
1	29.4	28.5	18.6	16.5	18.7	19.2
2	31.6	29.6	17.6	17.8	17.0	17.3
3	25.1	27.2	18.5	16.3	17.4	18.5
4	24.3	24.1	16.7	16.0	19.5	19.2
5	26.3	25.6	15.2	16.4	25.1	23.2
6	29.2	24.9	16.9	17.1	24.3	26.0
7	30.1	26.8	18.9	19.8	25.4	24.0
8	28.8	30.1	21.6	20.3	21.8	25.3
9	29.2	29.4	24.5	21.6	25.7	25.2
10	31.7	31.0	26.7	26.1	27.7	26.2
11	36.3	32.0	23.4	24.9	29.0	26.1
12	35.0	31.5	27.0	26.4	29.6	30.5

Table 4. Soil moisture percentages in the Buffalo Belt (sand) in six inch increments to a depth of six feet on three dates in 1970. Data are given for treatment (T) (clean-cultivated understory) and control segments (C) in the belt.

Depth	7/31/70		8/21/70		9/19/70	
	T	C	T	C	T	C
1	26.3	24.7	14.9	12.4	14.3	13.2
2	23.6	24.0	15.3	14.7	12.1	14.1
3	21.5	23.6	15.0	14.7	12.6	12.0
4	22.0	19.5	13.1	14.2	14.5	12.1
5	17.7	16.0	14.3	12.6	13.0	12.8
6	18.8	17.9	12.7	13.0	16.7	14.2
7	18.5	19.3	15.2	15.1	15.8	14.8
8	22.1	24.0	16.4	14.8	18.9	17.2
9	26.4	23.1	15.9	15.6	18.6	17.1
10	25.0	27.4	17.8	17.5	20.7	19.8
11	24.1	26.0	18.8	17.7	19.5	21.3
12	25.0	27.3	19.1	18.6	19.8	22.0

Table 5. Diameter (D), height (H), and growth increment (G) data on measured trees in Grandin Belt, 1969-70.*

		BOX ELDER				COTTONWOOD				AMERICAN ELM				SIBERIAN ELM				GREEN ASH			
		D	G	H	G	D	G	H	G	D	G	H	G	D	G	H	G	D	G	H	G
TREATMENT	1	5.45	.45	306.0	41.5	17.85	.65	727.5	31.5	5.80	.30	445.5	31.5	4.60	.15	435.5	10.5	4.90	.20	444.5	13.5
	2	6.05	.90	382.5	31.0	13.70	.40	720.5	19.5	5.55	.35	432.5	15.5	4.15	.20	394.0	14.5	6.25	.30	419.5	8.5
	3	10.25	.55	402.0	29.5	14.95	.40	768.5	10.3	6.05	.45	440.0	26.0	4.95	.15	401.0	9.5	6.25	.35	451.5	9.5
	4	6.30	.30	363.5	24.5	11.15	.55	685.3	7.5	6.15	.35	459.0	8.0	4.35	.35	374.5	9.0	6.70	.25	460.0	16.0
	5	6.95	.45	360.0	37.0	13.70	.65	603.8	28.2	6.40	.20	542.5	18.5	6.25	.25	381.0	15.5	6.25	.30	492.0	13.5
MEANS	1970		.521		32.7		.530		19.4		.330		19.9		.220		11.8		.280		12.2
	69-70		.521		42.3		.510		14.0		.310		16.8		.180		12.4		.265		19.3
CONTROL	6	7.85	.60	347.5	18.5	10.95	.45	657.4	5.8	4.90	.35	372.0	17.5	5.70	.25	522.0	10.5	5.20	.25	481.5	16.5
	7	10.95	.75	456.5	61.0	12.50	.25	635.6	4.1	8.55	.30	512.5	7.0	7.40	.15	478.5	7.0	5.55	.10	469.5	10.0
	8	10.90	105	433.0	42.5	15.20	.40	707.5	17.8	7.35	.45	498.0	12.5	4.10	.40	351.0	8.5	7.50	.25	469.0	7.5
	9	6.65	.35	459.5	65.0	15.35	.55	701.4	12.1	6.85	.35	561.5	24.5	7.20	.20	497.0	14.5	9.65	.35	543.5	0.5
	10	8.25	.35	401.0	30.5	10.95	.45	710.0	8.6	5.95	.35	472.5	25.5	7.20	.40	468.5	8.0	3.65	.35	327.5	13.5
MEANS	1970		.620		43.5		.420		9.7		.360		17.4		.280		9.7		.250		9.6
	69-70		.607		53.2		.410		21.9		.330		16.4		.380		6.8		.250		13.4

* All measurements in inches.

Table 6. Diameter (D), height (H), and growth increment (G) data on measured trees in Kindred Belt, 1969-70.*

		BOX ELDER				COTTONWOOD				AMERICAN ELM				SIBERIAN ELM				GREEN ASH			
		D	G	H	G	D	G	H	G	D	G	H	G	D	G	H	G	D	G	H	G
TREATMENT	1	6.85	.40	332.5	14.5	12.40	.50	693.4	17.7	6.90	.15	465.0	15.0	5.85	.35	236.5	14.5	3.25	.30	291.0	11.5
	2	5.65	.35	297.5	16.0	12.95	.30	618.0	20.8	5.20	.25	314.5	10.5	4.95	.20	265.0	6.5	5.40	.15	394.5	3.0
	3	5.90	.35	296.0	10.5	12.15	.45	639.8	8.7	6.95	.32	453.5	14.5	5.60	.40	330.0	18.0	5.30	.40	396.0	10.5
	4	4.05	.20	310.5	10.5	12.60	.40	719.5	18.5	6.05	.35	347.0	7.5					4.55	.45	351.0	15.0
	5	5.05	.35	304.5	17.5	15.95	.45	694.3	18.6	6.35	.40	493.5	15.0	2.25	.50	163.5	27.0	4.55	.25	344.5	6.5
MEANS	1970		.330		13.8		.420		16.9		.290		12.5		.360		16.5		.310		9.3
	69-70		.310		14.6		.485		24.6		.265		15.4		.335		15.2		.310		9.0
CONTROL	6	4.35	.25	274.0	7.5	13.55	.45	582.1	5.5	5.90	.20	673.0	5.5	4.80	.20	395.0	14.5	5.45	.10	427.5	18.5
	7	5.75	.15	350.5	8.5	11.30	.30	610.0	9.1	5.60	.10	428.5	11.5	5.25	.15	373.5	6.0	4.25	.15	379.0	11.5
	8					12.65	.20	638.9	16.4	4.65	.20	393.0	9.5	6.95	.15	439.5	6.5	7.35	.30	536.5	14.5
	9	6.30	.15	304.5	12.5	9.50	.30	507.1	14.1	8.05	.27	517.0	19.5	7.65	.35	410.0	8.0	4.65	.25	460.5	29.5
	10	6.00	.20	310.0	12.0	11.45	.25	555.2	5.4	6.30	.30	437.5	12.5	4.85	.13	428.5	8.5	5.85	.10	498.0	12.5
MEANS	1970		.190		10.1		.300		10.1		.210		11.7		.200		8.7		.180		17.4
	69-70		.215		11.3		.315		15.2		.190		10.8		.175		6.4		.185		19.9

* All measurements in inches.

Table 7. Diameter (D), height (H), and growth increment (G) data on measured trees in Arthur Belt, 1969-70.*

		BOX ELDER			COTTONWOOD				AMERICAN ELM				SIBERIAN ELM				GREEN ASH			
		D	G	H	G	D	G	H	G	D	G	H	G	D	G	H	G	D	G	H	G
TREATMENT	1	10.25	.35	461.0	5.5	12.90	.15	1017.1	52.2	3.95	.35	271.5	17.0	8.40	.20	646.0	23.5	8.85	.25	552.5	21.5
	2	9.00	.40	369.0	-2.5	15.35	.35	1042.6	8.4	5.75	.20	524.5	4.5					8.80	.30	603.0	19.5
	3	8.75	.15	439.5	6.5	7.55	.15	616.7	19.5	6.50	.10	437.5	9.5	6.65	.15	660.5	10.1	9.95	.30	593.0	7.5
	4	7.65	.30	446.0	17.0	14.95	.21	1021.2	16.1	4.80	.35	309.5	12.5	9.80	.60	741.5	37.0	8.25	.25	491.5	6.0
	5	7.90	.35	529.0	15.5	11.75	.10	819.7	6.9	7.25	.25	342.0	6.0	10.40	.40	826.0	13.1	6.10	.30	573.0	11.0
MEANS	1970		.310		8.4		.190		20.6		.250		9.9		.440		20.9		.280		13.1
	69-70		.440		13.9		.200		30.8		.210		13.2		.360		20.8		.240		15.2
CONTROL	6	8.90	.50	430.5	12.5	14.85	.45	994.3	24.2	4.70	.30	337.0	14.5	7.60	.20	563.0	13.2	4.50	.20	536.5	16.5
	7	9.55	.25	471.0	9.5	11.80	.25	865.7	23.5	5.45	.15	460.0	33.0	8.35	.15	638.5	13.8	9.60	.35	543.5	9.5
	8	5.25	.25	373.5	1.0	13.55	.45	881.5	9.1	4.45	.35	351.0	28.0	13.50	.25	710.5	7.2	7.45	.15	591.0	15.5
	9	6.90	.20	378.0	10.5	21.15	.30	1036.1	-3.2	6.35	.18	436.5	7.5	6.35	.15	596.0	21.6	4.90	.35	337.5	25.3
	10	6.25	.40	371.5	5.0	18.30	.45	987.0	18.6	5.05	.35	294.0	24.5	9.15	.35	692.0	17.6	6.20	.19	457.0	12.6
MEANS	1970		.320		7.7		.380		14.4		.270		21.5		.220		14.7		.250		15.9
	69-70		.315		7.6		.380		26.3		.275		23.0		.250		17.8		.200		13.5

* All measurements in inches.

Table 8. Diameter (D), height (H), and growth increment (G) data on measured trees in Buffalo Belt, 1969-70.*

		COTTONWOOD				AMERICAN ELM				GREEN ASH			
		D	G	H	G	D	G	H	G	D	G	H	G
TREATMENT	1	19.70	.70	881.9	39.6	7.55	.15	425.5	15.5	8.15	.20	467.5	29.5
	2	15.35	.50	830.2	17.4	6.25	.35	386.5	14.5	4.90	.20	422.0	40.5
	3	11.20	.40	751.6	21.2	4.45	.25	304.5	18.5	5.40	.30	449.0	23.0
	4	10.60	.35	919.0	15.8	6.50	.15	429.0	22.0	5.65	.15	392.0	17.5
	5	15.05	.55	896.2	21.3	6.45	.25	468.0	22.0	5.60	.40	448.0	24.0
MEANS	1970		.500		23.1		.230		18.5		.250		26.9
	69-70		.485		36.5		.205		22.8		.240		25.9
CONTROL	6	13.90	.40	951.4	48.4	6.60	.15	418.5	19.5	5.95	.25	503.0	20.5
	7	15.85	.20	903.8	31.4	7.40	.20	466.0	24.0	7.05	-.30	517.5	23.0
	8	20.35	.60	972.3	34.9	4.25	.25	326.5	9.5	6.90	.15	526.5	13.0
	9	9.30	.30	689.5	13.0	4.95	.10	359.5	9.0	6.10	.20	461.0	19.0
	10	15.05	.25	821.9	38.9	4.75	.15	321.0	7.0	6.65	.15	441.0	7.0
MEANS	1970		.350		33.3		.170		13.8		.090		16.5
	69-70		.345		46.4		.155		12.5		.235		18.1

* All measurements in inches.

APPENDIX TABLE 9. Diameter and height increment data of the trees of Grandin belt from 1968 to 1969.

	NO	YEAR	BOX ELDER				COTTONWOOD				AMERICAN ELM				SIBERIAN ELM				GREEN ASH			
			d	incr	h	incr	d	incr	h	incr	d	incr	h	incr	d	incr	h	incr	d	incr	h	incr
CULTIVATED	1	1968	4.39		243.5		16.60		756.1		5.18		414.0		4.37		419.0		4.55		399.5	
				.61		21.0		.60		39.9		.32		0.0		.08		6.0		.15		31.5
		1969	5.00		264.5		17.20		696.0		5.50		414.0		4.45		425.0		4.70		431.0	
		1968	5.04		286.0		12.92		649.1		4.90		399.0		3.83		372.5		5.75		386.5	
	2			.11		65.5		.38		51.9		.30		18.0		.12		7.0		.20		24.5
		1969	5.15		351.5		13.30		701.0		5.20		417.0		3.95		379.5		5.95		411.0	
		1968	9.35		292.0		13.90		756.1		5.28		408.0		4.45		365.5		5.60		431.0	
	3			.35		80.5		.65		2.1		.32		6.0		.35		26.0		.30		11.0
		1969	9.70		372.5		14.55		758.2		5.60		414.0		4.80		391.5		5.90		442.0	
		1968	5.80		297.0		10.19		675.2		5.55		418.0		3.93		362.5		6.31		416.0	
	4			.20		42.0		.41		2.6		.25		33.0		.07		3.0		.14		28.0
		1969	6.00		339.0		10.60		677.8		5.80		451.0		4.00		365.5		6.45		444.0	
		1968	5.17		272.5		12.65		549.0		5.95		512.0		5.93		342.5		5.48		441.0	
	5			1.33		50.5		.40		26.6		.25		12.0		.07		23.0		.47		37.5
		1969	6.50		323.0		13.05		575.6		6.20		524.0		6.00		365.5		5.95		478.5	
	TOTAL			2.60		259.5		2.44		123.1		1.44		69.0		.69		65.0		1.26		132.5
UNCULTIVATED		1968	6.18		260.5		10.09		650.2		4.15		352.5		5.20		509.5		4.80		418.0	
	6			.97		48.5		.41		1.4		.40		2.0		.25		2.0		.15		47.0
		1969	7.15		329.0		10.50		651.6		4.55		354.4		5.45		511.5		4.95		465.0	
		1968	9.35		346.0		11.65		573.0		7.85		407.5		7.03		469.5		5.25		459.5	
	7			.85		49.6		.60		58.5		.40		8.0		.22		2.0		.20		0.0
		1969	10.20		395.5		12.25		631.5		8.25		505.5		7.25		471.5		5.45		459.5	
		1968	9.65		319.0		10.79		625.9		6.89		457.5		2.60		342.5		6.88		455.5	
	8			.20		71.5		.36		22.1		.01		30.0		1.10		0.0		.37		6.0
		1969	9.85		390.5		14.80		689.3		6.90		487.5		3.70		342.5		7.25		461.5	
		1968	5.97		310.0		14.31		626.7		6.10		518.0		6.75		473.5		8.85		518.0	
	9			.33		84.5		.49		62.9		.40		19.0		.25		9.0		.45		25.6
		1969	6.20		394.5		14.80		689.3		6.50		537.0		7.00		482.5		9.30		543.0	
		1968	7.28		310.0		10.35		675.2		5.30		429.0		6.20		453.5		3.19		306.0	
				.62		60.5		.15		26.2		.30		18.0		.60		7.0		.11		8.0
		1969	7.90		370.5		10.50		701.4		5.60		447.0		6.80		460.5		3.30		314.0	
	TOTAL			2.97		314.5		2.01		171.1		1.51		77.0		2.42		20.0		1.28		86.0

APPENDIX TABLE 10. Diameter and height increment data of the trees of Kindred belt from 1968 to 1969.

	NO	YEAR	BOX ELDER				COTTONWOOD				AMERICAN ELM				SIBERIAN ELM				GREEN ASH			
			d	incr	h	incr	d	incr	h	incr	d	incr	h	incr	d	incr	h	incr	d	incr	h	incr
CULTIVATED		1968	5.76		292.0		11.48		323.4		6.54		440.0		5.29		218.0		2.85		270.5	
	1			.69		26.0		.42		52.3		.21		10.0		.21		4.0		.10		9.0
		1969	6.45		318.0		11.90		675.7		6.75		450.0		5.50		222.0		2.95		279.5	
		1968	5.02		269.5		12.14		574.4		4.64		300.0		4.58		239.5		4.99		382.5	
	2			.28		12.0		.51		22.8		.31		4.0		.17		19.0		.26		9.0
		1969	5.30		281.5		12.65		597.2		4.95		304.0		4.75		258.5		5.25		391.5	
		1968	5.49		279.5		11.12		599.0		6.47		408.0		4.68		299.0		4.00		373.5	
	3			.06		6.0		.48		32.1		.20		31.0		.52		13.0		.90		14.0
		1969	5.55		285.5		11.60		631.1		6.67		439.0		5.20		312.0		4.90		387.5	
		1968	3.69		284.5		11.72		674.4		5.92		354.5		3.81		204.0		4.08		332.0	
	4			.16		15.5		.48		26.6		.28		5.0		--		--		.02		4.0
		1969	3.85		300.0		12.20		701.0		5.70		559.5		Dead		---		4.10		336.0	
		1968	4.43		269.5		14.60		648.0		5.74		437.0		1.40		116.5		4.04		330.0	
	5			.27		17.5		.80		27.7		.21		41.5		.35		20.0		.26		8.0
		1969	4.70		287.0		15.40		675.7		5.95		478.5		1.75		136.5		4.30		338.0	
	TOTAL			1.46		77.0		2.69		161.5		1.21		91.5		1.25		56.0		1.54		44.0
UNCULTIVATED		1968	3.58		265.5		12.67		526.4		5.53		665.4		4.49		372.5		5.06		402.5	
	6			.52		1.0		.43		50.2		.17		2.0		.11		8.0		.29		6.5
		1969	4.10		266.5		13.10		676.6		5.70		667.5		4.60		380.5		5.35		409.0	
		1968	5.54		306.0		10.76		598.9		5.25		403.0		5.03		365.5		3.98		364.5	
	7			.06		36.0		.24		2.0		.25		14.0		.07		3.0		.12		3.0
		1969	5.60		342.0		11.00		600.9		5.50		417.0		5.10		367.5		4.10		367.5	
		1968	4.31		296.0		11.99		574.4		4.40		368.5		6.54		429.0		6.83		483.5	
	8			—		—		.46		48.1		.05		15.0		.26		4.0		.22		38.5
		1969	Dead		----		12.45		622.5		4.45		383.5		6.80		433.0		7.05		522.0	
		1968	6.10		286.0		8.91		493.0		7.41		487.5		7.12		400.0		4.22		387.5	
	9			.05		6.0		.29		0.0		.37		10.0		.18		2.0		.18		43.5
		1969	6.15		292.0		9.20		493.0		7.78		497.5		7.30		402.0		4.40		431.0	
		1968	5.47		291.0		10.98		549.0		6.00		417.0		4.49		416.0		5.63		464.0	
	10			.33		7.0		.22		0.8		.00		8.0		.13		4.0		.12		21.5
		1969	5.80		298.0		11.20		549.8		6.00		425.0		4.62		420.0		5.75		485.5	
	TOTAL			.96		50.0		1.64		101.1		.84		49.0		.75		21.0		1.03		113.6

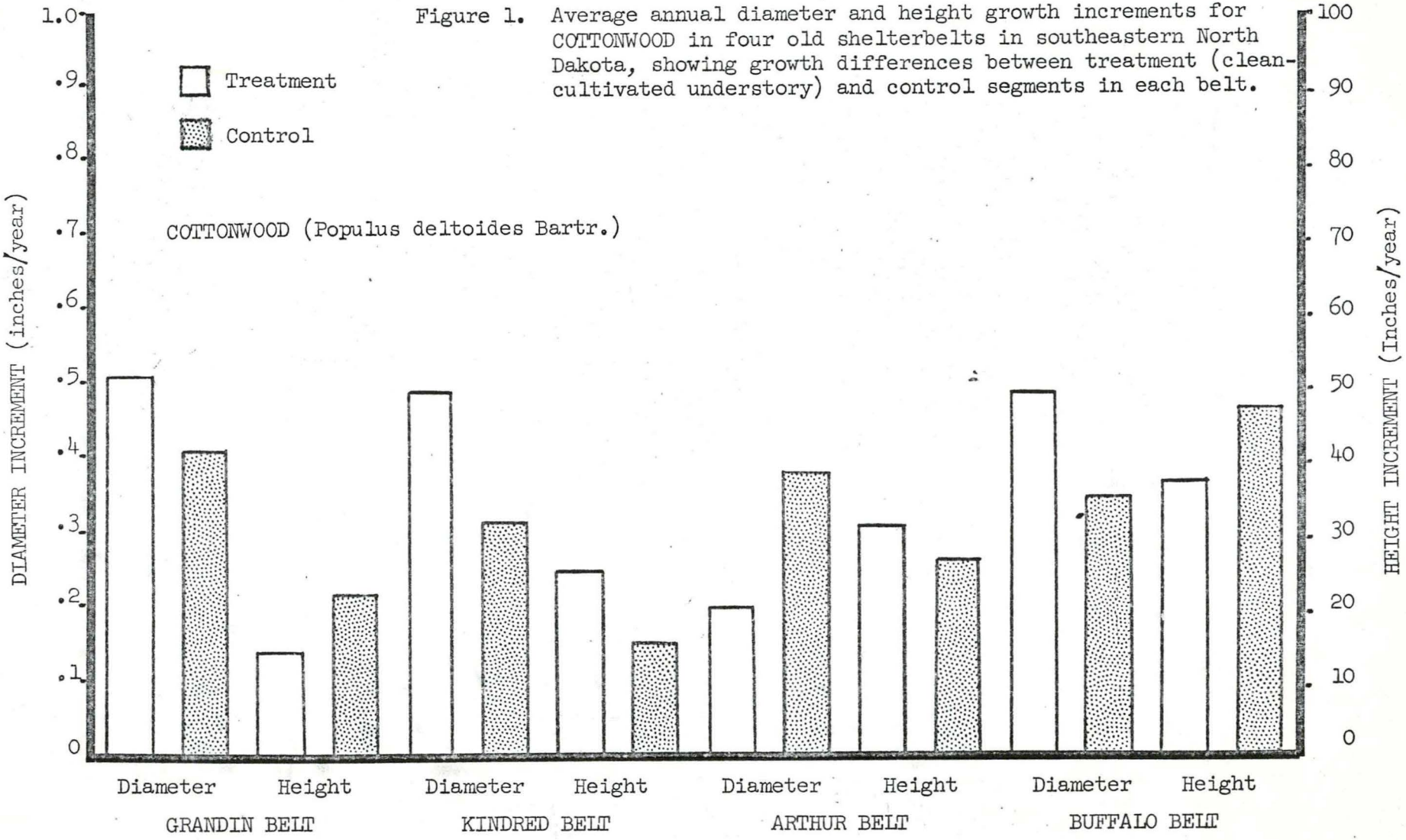
APPENDIX TABLE 11. Diameter and height increment data of the trees of Arthur belt from 1968 to 1969.

	NO	YEAR	BOX ELDER				COTTONWOOD				AMERICAN ELM				SIBERIAN ELM				GREEN ASH			
			d	incr	h	incr	d	incr	h	incr	d	incr	h	incr	d	incr	h	incr	d	incr	h	incr
CULTIVATED		1968	8.52		426.5		12.53		872.4		3.55		245.5		7.90		598.2		8.44		512.0	
	1			1.38		29.0		.22		92.5		.05		9.0		.30		25.3		.16		19.0
		1969	9.90		455.5		12.75		964.9		3.60		254.4		8.20		622.5		8.60		531.0	
		1968	8.30		365.5		14.50		1001.2		5.51		512.0						8.24		568.5	
	2			.30		6.0		.50		33.6		.04		8.0						.26		14.0
		1969	8.60		371.5		15.00		1034.2		5.55		520.0						8.50		582.5	
		1968	8.30		421.0		7.36		549.8		6.29		405.0		6.23		648.2		9.31		569.0	
	3			.30		12.0		.04		47.4		.11		23.0		.27		2.2		.34		16.5
		1969	8.60		433.0		7.40		597.2		6.40		428.0		6.50		650.4		9.65		585.5	
		1968	6.50		397.0		14.64		1000.5		4.28		269.5		8.91		676.5		7.89		467.0	
	4			.85		32.0		.10		4.6		.17		27.5		.29		28.0		.11		18.5
		1969	7.35		429.0		14.74		1005.1		4.45		297.0		9.20		704.5		8.00		485.5	
		1968	7.51		505.5		11.45		786.4		6.52		321.0		9.72		785.0		5.58		546.0	
	5			.04		8.0		.20		26.4		.48		15.0		.28		27.9		.12		16.0
		1969	7.55		513.5		11.65		812.8		7.00		336.0		10.00		812.9		5.70		562.0	
	TOTAL			2.87		87.0		1.06		204.5		0.85		82.5		1.14		93.4		.99		84.0
UNCULTIVATED		1968	8.15		415.0		14.05		906.3		4.31		265.5		7.35		547.8		4.20		512.0	
	6			.25		3.0		.35		63.8		.09		57.0		.05		2.0		.10		8.0
		1969	8.40		418.0		14.40		970.1		4.40		322.5		7.40		549.8		4.30		520.0	
		1968	8.50		437.0		11.32		842.2		5.00		380.5		8.08		622.5		9.05		516.0	
	7			.80		24.5		.23		0.0		.30		46.5		.12		2.2		.20		18.0
		1969	9.30		461.5		11.55		842.2		5.30		427.0		8.20		624.7		9.25		534.0	
		1968	4.90		368.5		12.94		843.2		3.96		319.0		12.86		701.8		7.02		568.5	
	8			.10		4.0		.16		29.2		.14		4.0		.39		1.5		.28		7.0
		1969	5.00		372.5		13.10		872.4		4.10		323.0		13.25		703.3		7.30		575.5	
		1968	6.62		365.5		20.20		1002.2		5.87		424.0		6.17		524.9		4.39		311.2	
	9			.08		2.0		.65		37.1		.30		5.0		.03		49.5		.16		1.0
		1969	6.70		367.5		20.85		1039.3		6.17		429.0		6.20		574.4		4.55		312.2	
		1968	5.53		362.5		17.35		907.4		4.01		259.5		8.00		624.7		6.00		423.0	
	10			.32		4.0		.50		61.0		.69		10.0		.80		49.7		.01		21.0
		1969	5.85		366.5		17.85		968.4		4.70		269.5		8.80		674.4		6.01		444.0	
	TOTAL			1.55		37.5		1.89		191.1		1.52		122.5		1.39		104.9		.75		55.0

APPENDIX TABLE 12. Diameter and height increment data of the trees of Buffalo belt from 1968 to 1969.

	NO	YEAR	BOX ELDER		COTTONWOOD		AMERICAN ELM		SIBERIAN ELM		GREEN ASH	
			d	incr	h	incr	d	incr	h	incr	d	incr	h	incr
CULTIVATED		1968	18.44		734.8		7.19		368.5		7.78		407.5	
	1			.56		107.5		.21		41.5		.17		30.5
		1969	19.00		842.3		7.40		410.0		7.95		438.0	
		1968	14.41		787.9		5.64		337.0		4.55		350.5	
	2			.44		24.9		.26		35.0		.15		31.0
		1969	14.85		812.8		5.90		372.0		4.70		381.5	
		1968	10.58		674.8		4.01		281.5		4.95		379.5	
	3			.22		55.6		.19		4.5		.15		46.5
		1969	10.80		730.4		4.20		286.0		5.10		426.0	
		1968	10.17		872.9		6.24		392.5		4.91		372.5	
	4			.08		30.3		.11		14.5		.49		2.0
		1969	10.25		903.2		6.35		407.0		5.40		374.5	
		1968	13.44		843.2		6.08		406.0		4.99		409.5	
	5			1.06		31.7		.12		40.0		.21		14.5
		1969	14.50		874.9		6.20		446.0		5.20		424.0	
	TOTAL			2.36		250.6		.89		135.5		1.17		124.5
UNCULTIVATED		1968	13.18		829.4		6.39		386.5		5.66		429.0	
	6			.32		73.6		.06		12.5		.04		53.5
		1969	13.50		903.0		6.45		399.0		5.70		482.5	
		1968	15.49		814.3		6.98		386.5		5.66		429.0	
	7			.16		58.1		.22		12.0		.24		10.0
		1969	15.65		872.4		7.20		442.0		7.35		494.5	
		1968	18.93		846.3		3.79		316.0		6.67		493.5	
	8			.82		91.1		.21		1.0		.08		20.0
		1969	19.75		937.4		4.00		317.0		6.75		513.5	
		1968	8.83		625.9		4.72		334.0		5.88		430.0	
	9			.17		50.6		.13		16.5		.02		12.0
		1969	9.00		676.5		4.85		350.5		5.90		442.0	
		1968	14.56		758.6		4.51		300.0		6.41		431.0	
	10			.24		24.4		.09		14.0		.09		3.0
		1969	14.80		783.0		4.60		314.0		6.50		434.0	
	TOTAL			1.71		297.8		.71		66.0		.47		98.5

Figure 1. Average annual diameter and height growth increments for COTTONWOOD in four old shelterbelts in southeastern North Dakota, showing growth differences between treatment (clean-cultivated understory) and control segments in each belt.



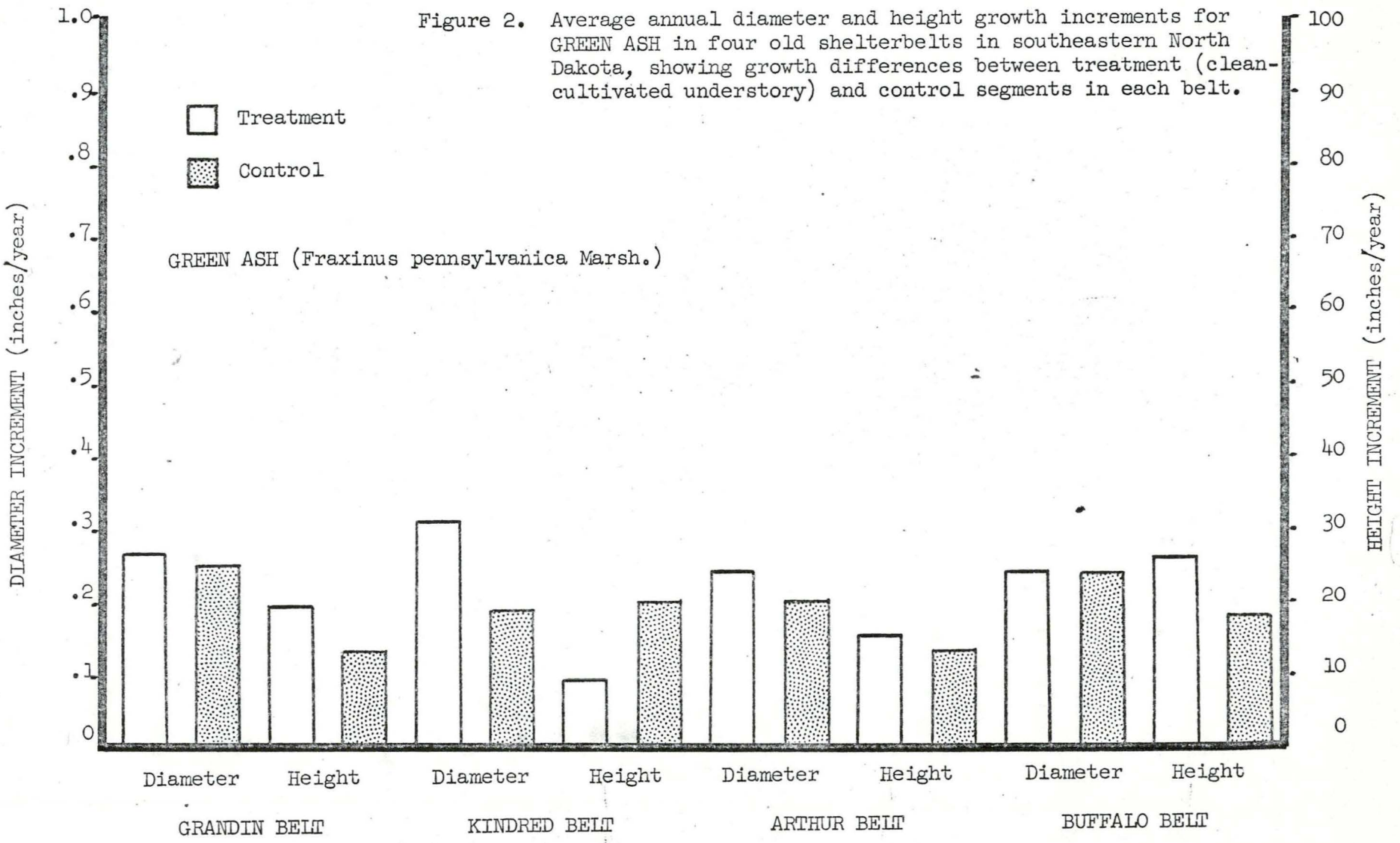


Figure 2. Average annual diameter and height growth increments for GREEN ASH in four old shelterbelts in southeastern North Dakota, showing growth differences between treatment (clean-cultivated understory) and control segments in each belt.

Figure 3. Average annual diameter and height growth increments for AMERICAN ELM in four old shelterbelts in southeastern North Dakota, showing growth differences between treatment (clean-cultivated understory) and control segments in each belt.

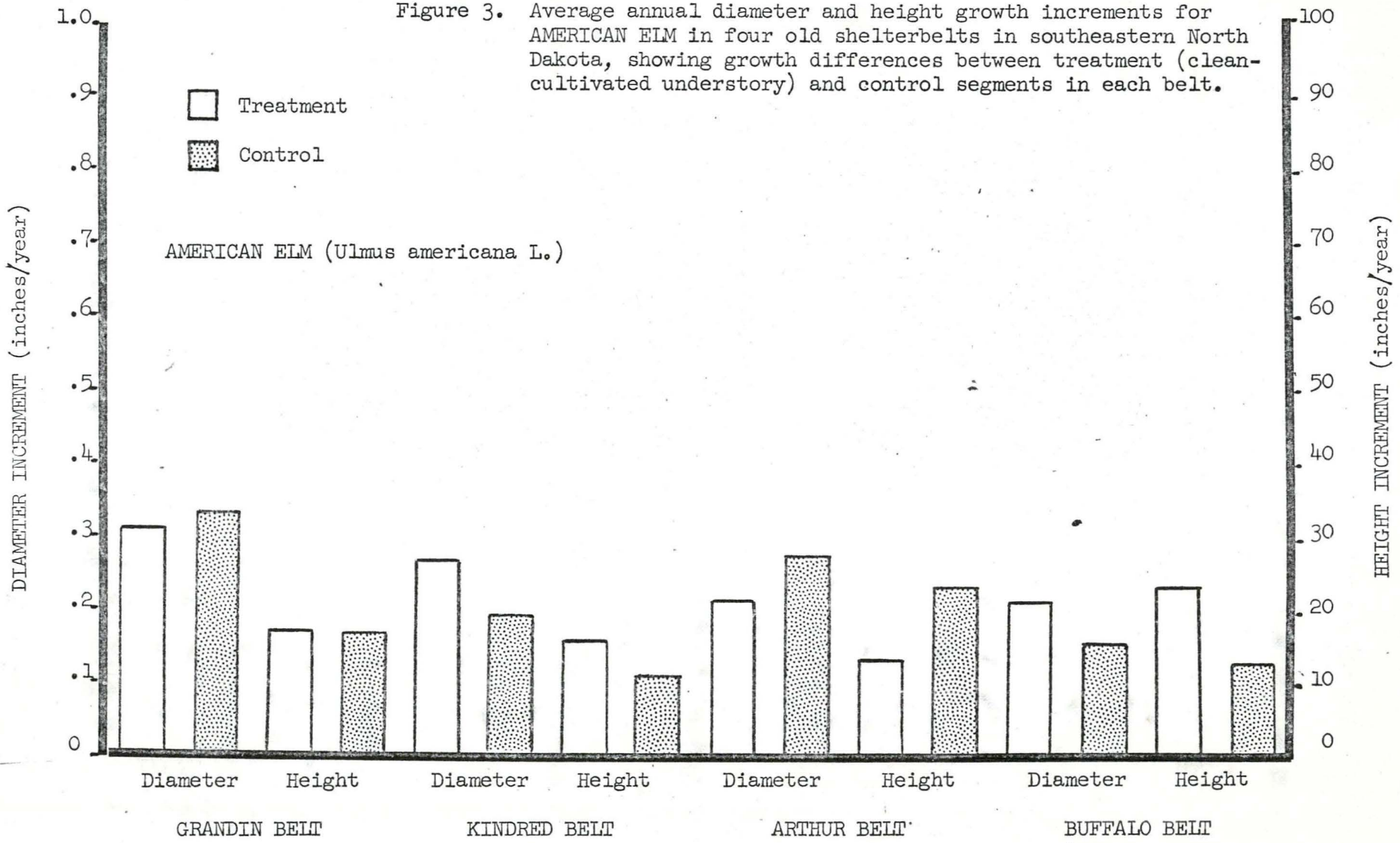


Figure 4. Average annual diameter and height growth increments for BOX ELDER in four old shelterbelts in southeastern North Dakota, showing growth differences between treatment (clean-cultivated understory) and control segments in each belt.

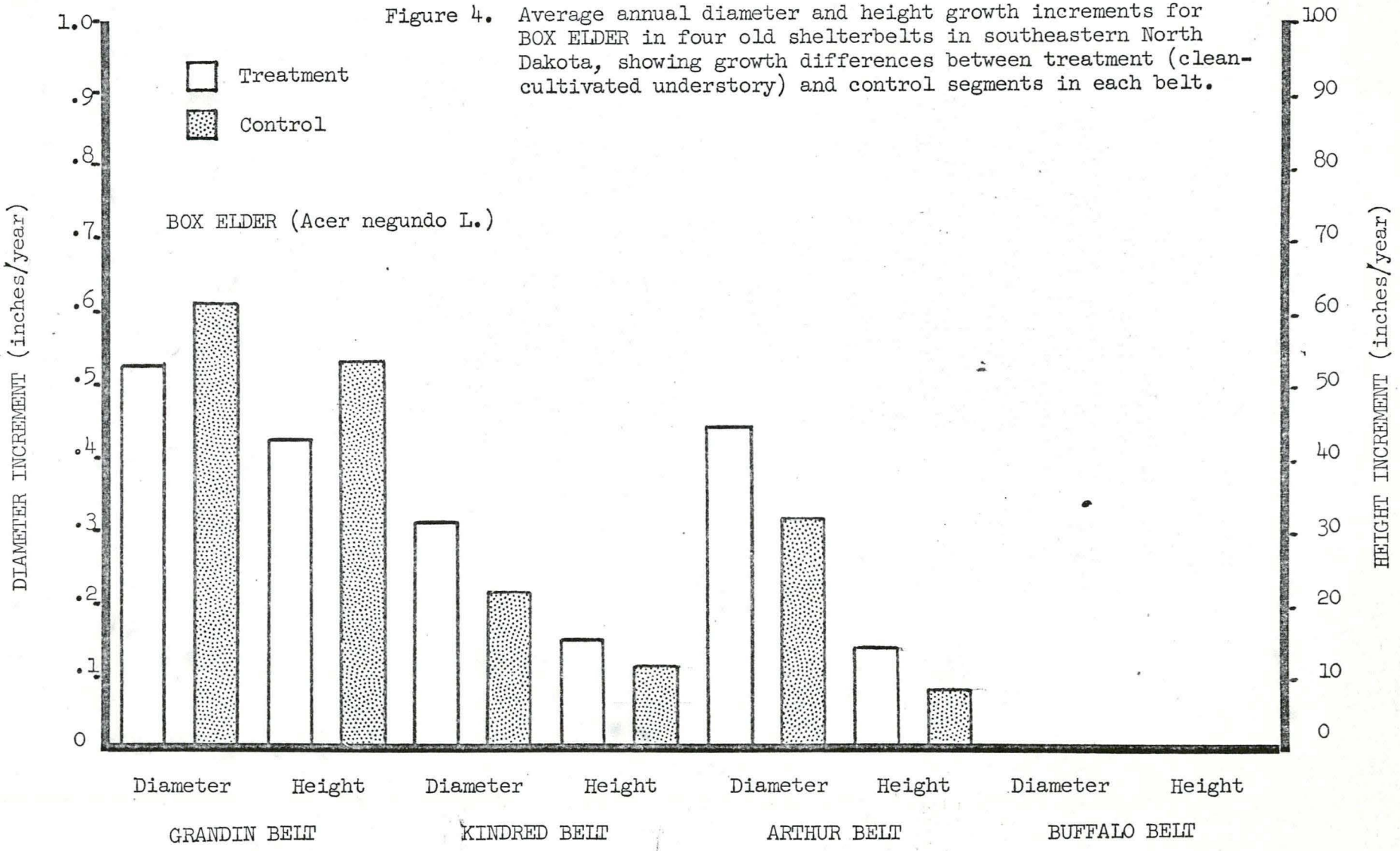
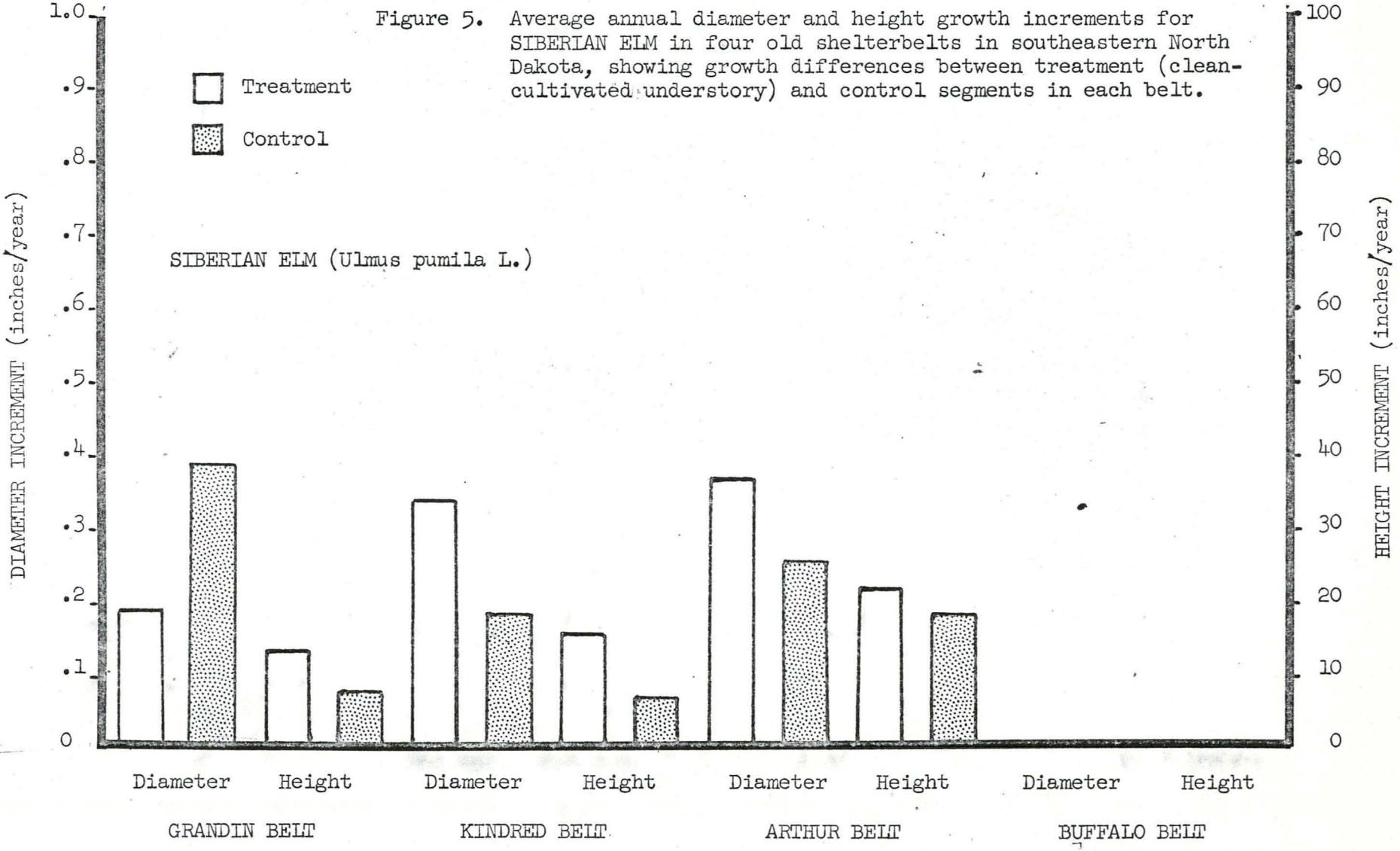


Figure 5. Average annual diameter and height growth increments for SIBERIAN ELM in four old shelterbelts in southeastern North Dakota, showing growth differences between treatment (clean-cultivated understory) and control segments in each belt.



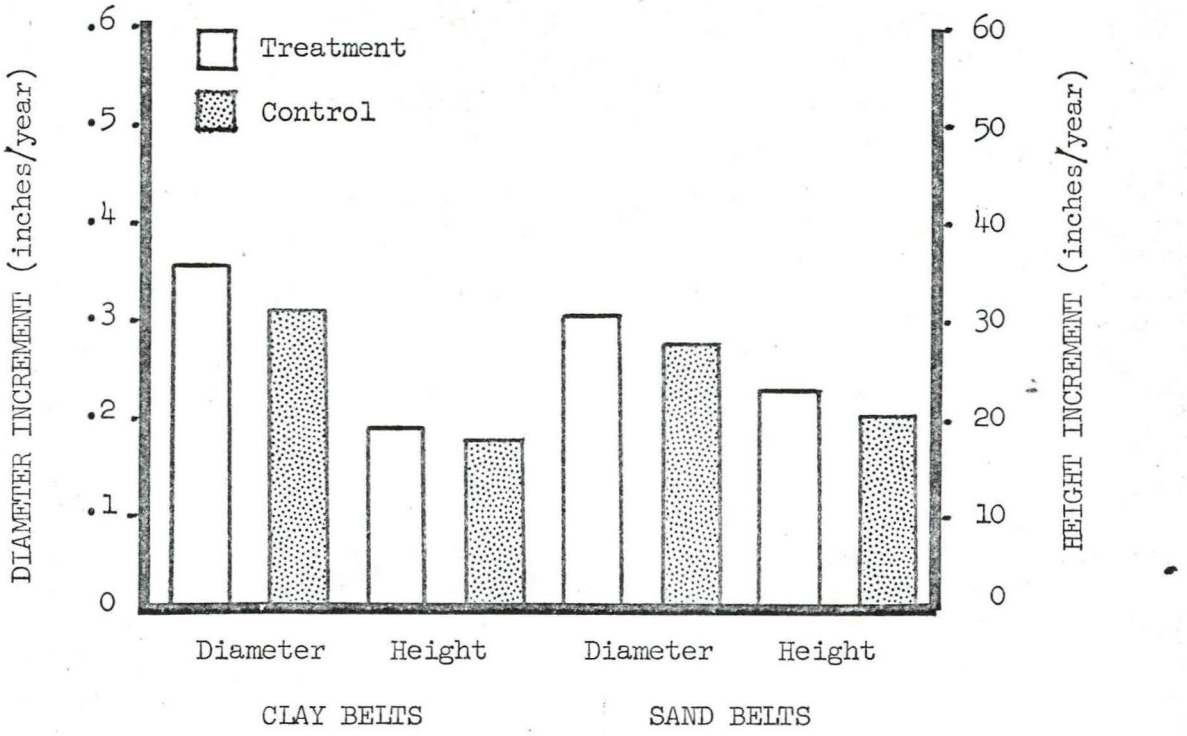


Figure 6. Average annual diameter and height growth increments for all species combined in four old shelterbelts in southeastern North Dakota, showing differences in growth between treatment (clean-cultivated understory) and control segments in each belt and growth differences between the clay belts (GRANDIN and KINDRED) and the sand belts (ARTHUR and BUFFALO).

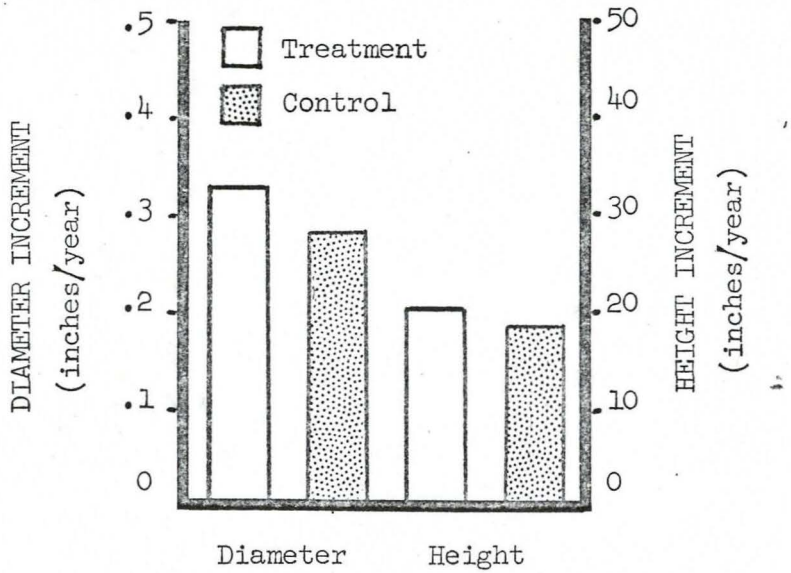


Figure 7. Average annual diameter and height growth increments for all species combined in all four belts studied in southeastern North Dakota, showing growth differences between treatment (clean-cultivated understory) and control segments.

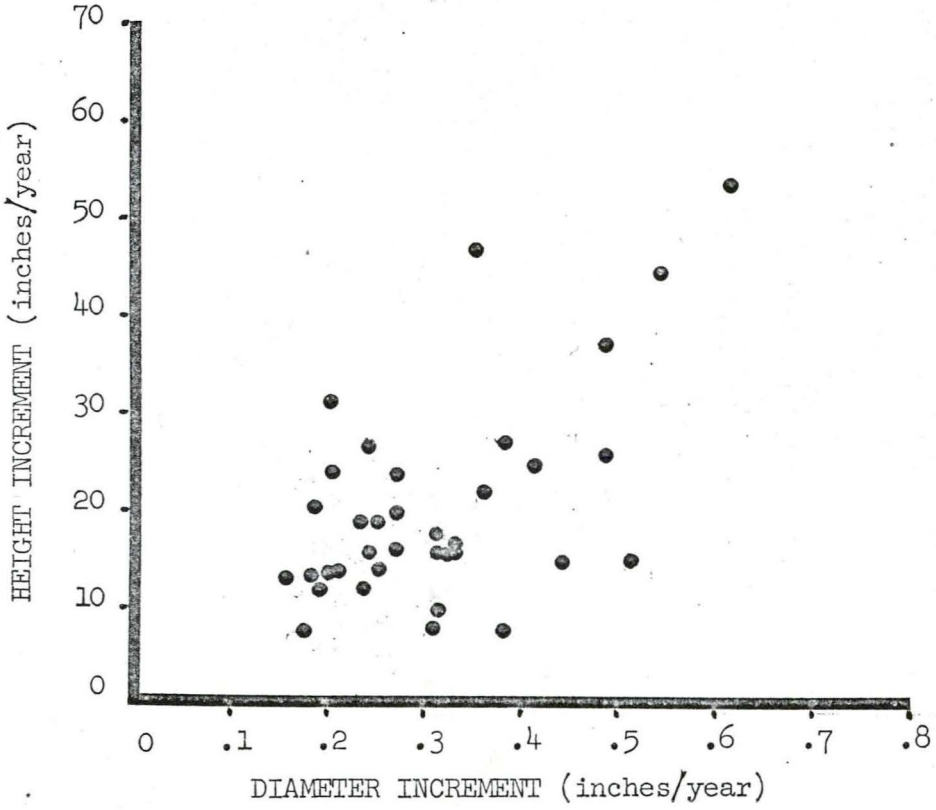


Figure 8. Scatter diagram showing the strong positive correlation between average annual diameter growth and average annual height growth increments. The points represent all measured individuals of all species in all segments in all four studied shelterbelts in southeastern North Dakota.

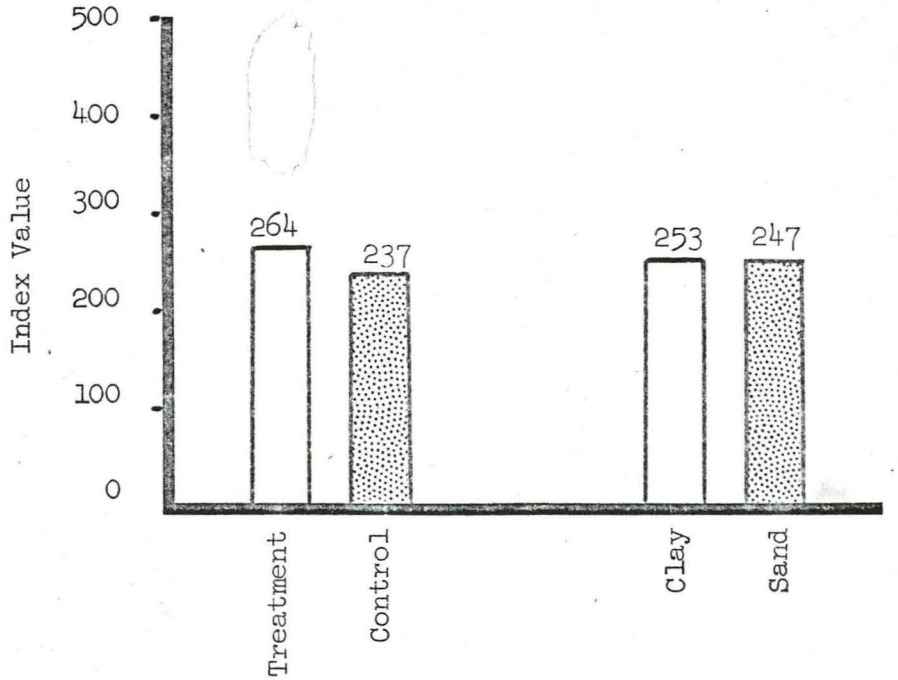


Figure 9. Artificial index values (I = 500X + 5Y, where X = average annual diameter increment, and Y = average annual height increment) for treatment (clean-cultivated understory) vs. control segments and clay belts vs. sandy belts comparisons. It is evident that treatment is more important than soil type in influencing tree growth in four shelterbelts in southeastern North Dakota.